Palaeogeography, Palaeoclimatology, Palaeoecology 569 (2021) 110222

Contents lists available at ScienceDirect

Palaeogeography, Palaeoclimatology, Palaeoecology

journal homepage: www.elsevier.com/locate/palaeo

Erratum to "Palaeoecological context for the extinction of the Neanderthals: A small mammal study of Stratigraphic Unit V of the El Salt site, Alcoi, eastern Spain" [Palaeogeography, Palaeoclimatology, Palaeoecology 530 (2019) 163–175]

The publisher regrets that the printed version of the above article contained a number of errors. The correct and final version follows. The publisher would like to apologise for any inconvenience caused.

Abstract

El Salt is an important reference site for understanding the extinction of Neanderthal populations in the eastern Iberian Peninsula during MIS 3. In this paper, we describe the small mammal assemblage from Stratigraphic Unit V, the youngest unit with evidence of human presence, based on nearly 1300 specimens. A total of seven rodents (*Microtus arvalis*, *Microtus duodecimcostatus*, *Microtus cabrerae*, *Sciurus vulgaris*, *Arvicola sapidus*, *Eliomys quercinus* and *Apodemus sylvaticus*), three insectivores (*Talpa occidentalis*, *Crocidura* sp., *Sorex* sp.) and one lagomorph (*Oryctolagus* cf. *cuniculus*) were identified. Palaeocological analyses point to drier conditions in this part of the stratigraphic sequence, supporting the hypothesis that an aridification scenario may have played a role in the extinction of the Neanderthal groups inhabiting this region of the Iberian Peninsula.

Keywords: Neanderthals, Small mammals, Iberian Peninsula, El Salt, Extinction, Palaeoclimatology

1. Introduction

The timing and possible causes of Neanderthal extinction remain unresolved and continue to be strongly debated (d'Errico and Sánchez-Goñi, 2003; Stewart, 2005; Finlayson et al., 2006; Banks et al., 2008; Mallol et al., 2012; Zilhão, 2013; Galván et al., 2014b; Higham et al., 2014; Villa and Roebroeks 2014; Kolodny and Feldman, 2017; Wolf et al., 2018; Ríos et al., 2019). The replacement of Neanderthals by anatomically modern humans (AMH) is recorded across Europe by a diachronous and culturally complex succession of distinct stone tool assemblages from the Middle-Upper Palaeolithic transition (MUPT) roughly between 48 and 36 ka cal BP (Staubwasser et al., 2018). Improved dating of the Middle-Upper Palaeolithic boundary is providing a better understanding of this biological replacement process (Marín-Arroyo et al., 2018 and references therein). Recent research centred on the Iberian Peninsula points to regional extinction of Neanderthals at different moments and persistence in the south (Zilhão et al., 2017; Marín-Arroyo et al., 2018; Wolf et al., 2018; Cunha et al., 2019), although the precise nature of timing of the replacement of *H. neanderthalensis* by AMH in the Iberian Peninsula remain unresolved questions (Strauss, 2018).

Climate has always been considered as an influential factor involved in biogeographical reordering. Thus, in the 1980s, several authors proposed a scenario that involved climate change as a factor in the replacement of Neanderthals by anatomically modern humans (AMH) (Leroyer and Leroi-Gourhan, 1983; Leroyer, 1988). Since then, many other authors have considered that climate must have played a role in Neanderthal extinction (Mellars, 1992; Djindjian, 1993; Zilhão, 1993; Burjachs and Julià, 1996). In this sense, Finlayson et al. (2004) point out that the whole issue of Neanderthal extinction may be addressed from an ecological and palaeoclimatic perspective and d'Errico and Sánchez-Goñi (2003) projected a climate driven model for the extinction of Iberian Neanderthals based on millennial-scale palaeovegetation data and palaeoclimatic models that plays down the influence of AMH. Other authors including Stewart (2005), analyze fauna present during MIS 3 and set forth evidence of an ecological downturn influenced by climate in which mammoths disappeared, certain species –including Neanderthals– disappeared, and AMH expanded throughout Europe and Asia.

Palaeoclimatic records from a wide range of marine and terrestrial archives document rapid fluctuations during the last glacial and provide compelling evidence that Dansgaard Oeschger oscillations (D/O) and Heinrich cold events (HE) were of global significance (Moreno et al., 2002). During HE 4 and the rest of the HE in MIS 3, the Mediterranean region had a mean annual precipitation of 400 mm, a minimum temperature of the coldest month, between 6 and 13 °C less than current conditions and a maximum temperature of the warmest month of 10 °C (Sánchez-Goñi and d'Errico, 2005). Coinciding with these cold stages, northeastern and southern winds would have prevailed (Moreno et al., 2002). During temperate phases of MIS 3, temperature and precipitation estimates indicate that climate was similar to nowadays (Sánchez-Goñi and d'Errico, 2005). In the light of these data, climate could be considered as a factor that played a significant role in population dynamics of the Iberian Peninsula at the Middle-to-Upper Palaeolithic boundary (Mallol et al., 2012; Galván et al., 2014b).

Sedimentary sequences covering this timeframe or archaeological sites with Middle and Upper Palaeolithic records are interesting places to study the Middle to Upper transition as they might provide clues to contextualize the environment and to evaluate the possible effects of climate on these populations. According to Holmes et al. (2010), "Although large-scale reconstructions using, for example, marine sediments provide a valuable environmental context for hominin evolution, they must be complemented by smaller-scale, site-specific environmental investigations from localities closer or where the hominin remains have been found". From this perspective, small mammals, which currently make up around 80% of current and past mammal species diversity (Fernández-Jalvo et al., 2016), are tightly linked to

DOIs of original article: https://doi.org/10.1016/j.palaeo.2021.110221, https://doi.org/10.1016/j.palaeo.2019.05.007.

https://doi.org/10.1016/j.palaeo.2021.110222

Available online 12 January 2021

environmental variations and have precise ecological requirements (Delany, 1976; Stoddart, 1979). Thus, they constitute a powerful tool for palaeoclimatic and palaeoenvironmental approaches in archaeological sites (Chaline, 1988; Cuenca-Bescós et al., 2009), especially in rapidly changing periods such as the one studied here.

With this contribution, we would like to connect our results with the debate on the extinction of Neanderthals during MIS 3, in order to shed light on the environmental context in which these groups developed and disappeared. Palaeoclimatic reconstructions for this period are crucial to clarify whether or not climate deterioration played a crucial role in driving Neanderthals extinction at a regional scale.

2. El Salt site

El Salt is a middle Palaeolithic site located in the municipality of Alcoi (Alicante, southeastern Iberia, Spain), 680 m above sea level. Its 6.3 m thick stratified deposit rests against a 38 m-high Palaeocene limestone wall, formed at a thrust fault and covered with tufa and travertine (Fig. 1). Since 1986, El Salt has been studied systematically from an interdisciplinary perspective, focusing on the high resolution studies of Neanderthal behaviour (Galván et al., 2006; Mallol et al., 2013; Garralda et al., 2014; Sistiaga et al., 2014; Rodríguez-Cintas and Cabanes, 2015; Machado and Pérez, 2016; Molina, 2016; Vidal-Matutano, 2017; Pérez et al., 2017; Marquina et al., 2017; Machado et al., 2017; Fagoaga et al., 2018; Vidal-Matutano et al., 2018; Leierer et al., 2019).

The sedimentary sequence comprises thirteen lithostratigraphic units (XIII to I, oldest to youngest) described by Fumanal (1994) and Galván et al. (2014b) (Fig. 2a). Unit XIII, the oldest unit, consists in an archaeologically sterile subhorizontal travertine platform. Overlaying, Units XII to IX contain the highest concentration of archaeological remains and combustion structures (Leierer et al., 2019); these units are 1.5 m-thick and are mainly constituted by horizontally-bedded fine sand. From Unit VIII to the middle of Unit V there is considerably spatially-reduced evidence of human input and progressively more non-archaeological sedimentation (Galván et al., 2014b). Six upper teeth of possibly a Neanderthal juvenile or young adult were recovered at the base of Unit V (Garralda et al., 2014). According to Galván et al. (2014b), "these specimens could represent an individual from one of the last Neanderthal groups that occupied the site and perhaps the region". The upper part of Unit V is archaeologically sterile except for the upper part, where two small flint blades, a few undifferentiated flakes, and a small combustion structure were recovered at the top of the unit (Garralda et al., 2014). This segment, the upper part of Unit V, is 50 cm-thick, truncated by a massive sandy silt with heterogeneous gravel in the uppermost 20 cm. Preliminary results from a small mammal study showed a reduction in species diversity in Unit V compared with all of the underlying units (Fagoaga et al., 2015). Holocene Units IV to I consist on different beds of gravel in secondary position and separated by erosional contacts. They contain late Upper Palaeolithic, Epipalaeolithic and Mesolithic lithic remains and Neolithic pottery remains (Fig. 2a) (Galvan et al., 2014).

3. Material and methods

The small mammal fossil remains used for this study consist mainly of isolated dental fragments collected during the 2013 and 2014 field seasons at El Salt. In order to relate findings to the anthropogenic context, the excavation methodology implemented at El Salt was based on the identification and excavation of paleosurfaces. These paleosurfaces were identified based on sharp stratigraphic contacts, textural or lithological changes and lateral associations between large objects.

This study includes Upper Unit V-24, which yielded three excavation surfaces (7, 8 and 9) and Upper Unit V-25. These two segments have been dated to around 45 ka; between HE 5 and HE 4 (Galván et al., 2014a, 2014b) (Fig. 2a). We also include Unit Xb, previously studied in Fagoaga et al. (2018) to compare a period of recurrent human occupation (Unit Xb) with the context of human disappearance recorded in Upper Unit V. Upper Unit V-24 consists in silts with coarse sand and gravel (1–3 mm) and minor amount of heterometric limestone and travertine fragments. This segment of the sequence overlies the Upper Unit V 50 cm-thick archaeologically sterile deposit (Upper Unit V-23) (Fig. 2c). Upper Unit V-25 comprises a massive fine-grained deposit similar to Upper Unit V-23 (Fig. 2b and c).

Fossil remains were obtained from two different sources: complete water sieving with 0.5 mm mesh size from several excavation squares and flotation with a 1 mm mesh (Vidal-Matutano, 2017). Analyses depending on relative abundances (Habitat Weightings method and taphonomy) were carried out only from the material collected from the water sieving method; Potentially, the latter method contains all the small mammal remains fractions and not only fossil remains over 1 mm as in the case of the flotation method. However, in order to identify as many species as possible, the material resulting from the flotation process was also examined for systematic palaeontological and palaeoclimatic analysis. The fossils were processed, sorted and classified using a Leica MS5 binocular microscope. Measurements were taken on a Leica MZ75 binocular microscope, by means of displacement of a mechanical stage connected to Sony Magnescale measuring equipment. Photographs were taken with a scanning electron microscope at The Central Support Facility for Experimental Research (SCSIE) of the Universitat de València.

Fossils were identified following the anatomical nomenclature and measurements methods given by van der Meulen (1973), Rabeder (1981) and Jeannet (2000) for arvicolines, Van der Weerd (1976) for murids, Daams (1981) and Freudenthal (2004) for glirids, Reumer (1984) for soricids and finally, Furió (2007) for erinaceids. The taxonomic classification follows the one given by Wilson and Reeder (2005). Within arvicolines, subgeneric classification follows Jaarola et al. (2004).

To reconstruct the palaeoenvironment at Unit V from El Salt, we used the Habitat Weightings method developed by Whittaker (1948), Rowe (1956) and Gauch (1989). Fossils were grouped using the minimum number of individuals (MNI) method, by which we determined the sample by counting the best diagnostic elements, considering laterality. This procedure defines a value, in a range between 0 and 1, for each species in each habitat where it is possible to find it. According to Cuenca-Bescós et al. (2005), the habitats used are: Open dry (OD), meadows under seasonal climate change; Open humid (OH), evergreen meadows with dense pastures and suitable topsoil; Woodland (W), mature forest including woodland margins and forest patches, with moderate ground cover; Rocky (R), areas with a suitable rocky or stone substratum, and Water (Wa), areas along streams, lakes and ponds. Values have been assigned from the available information at "Atlas y Libro Rojo de mamíferos terrestres de España" (Palomo et al., 2007).

Taxonomical composition of the assemblage allows us to evaluate the climatic conditions that prevailed during the formation of the studied deposit (Hernández-Fernández and Peláez-Campomanes, 2005). To approach to those conditions, we have used the Mutual Ecogeographic Range method (MER) (Blain et al., 2009; Blain et al., 2016), which consists in identifying the geographic regions where all the species from a same assemblage live nowadays and extrapolate the current mean values of climatic parameters to our unit. An assumption that must be considered is that the fossil representatives of the extant species have the same climatic tolerances and preferences as their living counterparts. This method suggests avoiding species whose distribution is strongly affected by perturbing parameters as human pressure. Thereby, *Microtus cabrerae* has been removed from this study because it has suffered a range contraction (Laplana and Sevilla, 2013) and many subpopulations are small, fragmented and subject to major inter-annual fluctuations (Palomo, 1999; Palomo and Gisbert, 2002). From a 10 × 10 km square grid, Palomo et al. (2007) record the presence or absence of each mammal taxa recorded in Spain. Using ArcGis application, and

from species identified in the Stratigraphic Unit (SU), and considering the resulting distribution area of the whole fossil assemblage represented in each level analysed, we have extracted bioclimatic information (MAT, mean annual temperature; MTW, maximum temperature of the warmest month; MTC, minimum temperature of the coldest month; MAP, mean annual precipitation) contained in climate layers from World Clim 1.4 with 30 arcseconds resolution grid (Hijmans et al., 2005), calculating the same climatic parameters for Alcoi nowadays. Therefore we can compare values of the past with the current ones in the same geographic location.

In order to assess the homogeneity of the environment in each of the assemblages studied, we have calculated the Simpson index of Evenness = 1-∑(pi2), where pi is the proportion of individuals in the ith species (Magurran, 2004). This index ranges from 0 to 1, where values close to 1 mean there is no variation in the species within a community. Contrary, the higher variation, the lower is the value of the evenness index. Values have been standardized by dividing by total sample abundances to avoid statistical problems of high sample-size dependence.

On the other hand, species identified have been classified according to chorotypes established by Sans-Fuentes and Ventura (2000), Real et al. (2003) and López-García et al. (2010). Chorotype 1 (Ch1) refers to species with Euro-Siberian requirements; Chorotype 2 (Ch2) are form by Euro-Siberian species that nonetheless tolerate Mediterranean conditions; Chorotype 3 (Ch3) includes strictly Mediterranean species; and finally Chorotype 4 (Ch4) denotes species with a broad distribution and without very strict Mediterranean requirements. Ch1 and Ch2 have been joined in an upper group related with Euro-Siberian conditions, while Ch3 and Ch4 have been linked in another group more related to Mediterranean conditions.

Using GIS tools, we linked the cartography of vegetation series in the Iberian Peninsula (Rivas-Martínez, 1987) with mutual distribution range of the fossil species (currently extant) recorded at the site. From this analysis, we reconstructed the probable vegetal landscape and its bioclimatic determinants existing around the site at the time of its formation. To analyze the developed changes in communities, we compared the vegetal landscape and bioclimatic indexes that characterize the surroundings of the site (Alcoi municipality) nowadays according to Rivas-Martínez (1987) with those previously obtained for the time of formation of the site.

In order to assess the possible taphonomical bias introduced and to allow these palaeoecological interpretations of the fossil assemblage, a preliminary study was conducted in order to identify the predator responsible for the accumulation (Andrews, 1983, 1990; Andrews and Evans, 1983; Fernández-Jalvo and Andrews, 1992). Among digestion, skeletal representation and breakage, only the first parameter cannot be simulated by any taphonomical agent besides gastric juices from raptors and/or carnivores. Based in the descriptive-systematic method developed by Andrews (1990), Fernández-Jalvo and Andrews (1992), and Fernández-Jalvo et al. (2016), digestion has been analysed for teeth (molars and incisors).

The following abbreviations are used: **AMH:** anatomically modern humans; **GI**, Greenland Interstadial; **GS**, Greenland Stadial; **HE**, Heinrich Event; **ka cal BP,** calendar years before present; **kyr,** 1,000 years; **L**, Length; **m**, mean of the minimum temperatures of the coldest month; **M**, mean of the maximum temperatures of the coldest month; **Md**, Hemimandible; **Mx**, Maxille; **MAT**, Mean Annual Temperature; **MTW**, maximum temperature of the warmest month; **MTC**, minimum temperature of the coldest month; **MAP**, Mean Annual Precipitation; **MIS**, Marine Isotope Stage; **SCSIE (UV)**, Servei Central de Support a la Investigació Experimental de la Universitat de València; **SU**, Stratigraphic Unit; **W**, Width.

4. Results and discussion

4.1. Taphonomic remarks

Although we did not carry out a complete taphonomic study of the small mammal accumulation at El Salt Unit V, some preliminary results can be pointed out. Within each sample studied, bones and teeth show a relatively homogeneous preservation. No items with abraded or polished surfaces or edges have been identified, suggesting that transport of the remains on the surface prior to their burial was short or null. There are no significant colour differences between remains within each sample. No other possible evidence of reworking has been identified (such as polishes on root-marks, for example). All these features suggest the absence of mixing processes by reworking. The main difference between the remains within each sample concerns the evidences of digestion. Digestion features found on the fossils analysed show the predominance of non-digested remains and little modification on the enamel surface. However, higher degrees of digestion were identified in a very low proportion. The percentages of digestion observed seen on molars and incisors are around 50 and 25%, respectively. These results allow us to associate our assemblage to the action of predators, specifically a predator of digestion category 3. Given the size of prey from the assemblage identified, the European eagle owl (*Bubo bubo*) appears to be the most plausible predator responsible for this faunal association.

4.2. Small mammal assemblage

The associations studied comprise 1,249 dental remains corresponding to 97 individuals and 15 species. The species determined are listed in Table 1. In general, qualitative differences among the faunal lists from the Unit V surfaces analysed are not significant. However, the species *Talpa occidentalis*, *Arvicola sapidus* and *Sciurus vulgaris* are only present in some of the surfaces (Table 1). *Sciurus vulgaris* and *Talpa occidentalis*, previously undocumented at El Salt, were found in Unit V Surfaces 9 and 7 (Table 1).

Comparing the faunal list of Unit V and those from the older unit Xb, the main difference is the presence of *Erinaceus europaeus* and *Microtus agrestis* in the unit Xb and its absence in the upper Unit V (Fagoaga et al., 2018). In sum, the units analysed from El Salt have yielded a faunal record with low variability in taxonomical terms, as it occurs with other Iberian sites such as L'Arbreda Cave (covering the Mousterian to the Upper Solutrean) (López-García et al., 2015).

From the species identified at Unit V, *Arvicola sapidus*, *Microtus arvalis*, *M. cabrerae* and *Talpa occidentalis* are not currently located in the municipality of Alcoi.

Taking into account the chorology of the species, our results generally show a trend towards an increment in the number of the species related to Mediterranean requirements, and in parallel a reduction in those with Euro-Siberian affinities (Table 1). Nevertheless, this tendency changes in Upper Unit V-24 Surface 7 (Fig. 3).

4.3. Palaeoenvironmental reconstruction

Habitat Weighting method developed by Whittaker (1948), Rowe (1956) and Gauch (1989) and the available information contained at "Atlas y Libro Rojo de mamíferos terrestres de España" (Palomo et al., 2007), allow us to characterize the small mammal assemblages studied from the units Xb and V (Upper Unit V-24-Surfaces 7, 8 and 9 and V-25) at El Salt (Table 2). The results show the predominance of woodland habitats throughout the sequence, being represented mainly by the presence of *Apodemus sylvaticus* (most abundant taxon in the whole of Unit V). Its abundance is only substituted in the younger samples from V-24-Surface 7 and V-25 by more open environment species such as *Oryctolagus cuniculus* and *Microtus arvalis* (Table 2; Fig. 4).

Only in the case of Unit V S.7, values for woodlands are slightly under 50% (Table 2; Fig. 4). The main differences among the

palaeoenvironmental reconstructions rely on water and open dry habitats. Water habitats decrease from the oldest to the youngest association, marked by *Arvicola sapidus*, linked to stable water sources in the surroundings. This species is present in all Unit Xb and V assemblages, except in the youngest sample (Unit V-25). Open dry habitats show the opposite trend: abundance of species associated with open dry environments rise in number through the sequence analysed, especially *Microtus arvalis*, with mid European requirements, cold climates and open landscapes (Sans-Fuentes and Ventura, 2000; Palomo et al., 2007).

Results provided by the small mammals indicate a patchwork landscape, with great variability of habitats (Fig. 3).

In order to know the magnitude and the nature of the relation between habitats and the assemblages, a correspondence analysis was conducted. Distance values along the axis of the correspondence analysis show more proximity to woodland and humid habitats in the older surfaces. Younger samples, palaeoecologically different from the older ones, appear more separated from such habitats. These results show a changing environment in which extreme ecological differences appear in the youngest and the oldest assemblage (Xb and V-25) (Fig. 5b). Rocky and water habitats are the farthest habitats and therefore less represented. However, rocky habitats should have had a relevant weight as the site is located in a huge rock shelter. A possible explanation is that small mammals are more linked to vegetation cover rather than rocky habitats, contrary to what is seen on reptiles. On the other hand, the representation of water habitats is in accordance with Mediterranean climates, where rainfall and therefore water sources are not as abundant (Rivas-Martínez, 1987).

Regarding cluster analysis, two main groups stand out. The older assemblages have been included in one group, in which surfaces from unit V have been placed separately from the older sample from unit X, denoting different conditions. In the second group, the younger samples are grouped together, reaching the highest similarity values between excavation Surfaces 9 and 8 (<0,005) (Fig. 5a).

The correspondence analysis and cluster analysis show clear different conditions for the upper assemblages (S7 and V-25) (Fig. 5a), deflected to more open and arid environments in regard to the lower levels (Fig. 5b). Thus, there is a palaeoecological trend from a more closed and humid habitat to a more open landscape in the span between the older and the younger assemblages.

Compared to other MIS 3 Iberian archaeological sites (Abric Romaní, L'Arbreda Cave, Canyars, Teixoneres, Cova dels Xaragalls, Cova del Gegant, Goram's Cave and Cova Eirós) (López-García et al., 2008, 2012a,b, 2014, 2015; González-Sampériz et al., 2010; Rey-Rodríguez et al., 2016), available palaeoenvironmental data are in agreement with our results: landscapes were dominated by open-forest formations in all cases. Overall, previous research has led to interpretation of NE Iberia MIS 3 palaeoenvironments featuring a transition from more forested conditions at the beginning of this period to more open and colder environments towards the end (López-García et al., 2012a,b, 2014, 2015; Fernández-García et al., 2016). At L'Arbreda Cave, a reduction in MAP and woodland landscapes as well as an increment of the MAT has been documented the same chronology (López-García et al., 2015). Likewise, the results obtained in assemblages from El Salt Unit Xb to Unit V also show a tendency to reduction of the forest cover and the development of more open environments (Fig. 3).

On the other hand, results for biodiversity through the Simpson Index show values for the different samples analysed ranging from 0.83 to 0.85. These values indicate high diversity in all the samples, which are relatively equally distributed. Comparing our results with other contexts of similar chronology in the East of the Iberian Peninsula, the former would be similar to those from Mousterian level I at L'Arbreda Cave (level I: 0.84) (López-García et al., 2015), Galls Carboners level H3 (0.83) (López-García et al., 2014) and the Aurignacian level 2 at Cova Eirós (level 2: 0.84) (Rey-Rodríguez et al., 2016). The most significant differences can be observed between the values of El Salt excavation surfaces and those of Mousterian level 3 at Cova Eirós (Level 3: 0.88) (Rey-Rodríguez et al., 2016) and, especially Cova del Rinoceront level VII (level VII: 0.69) where the assemblage is dominated by *A.* cf. *sylvaticus* (López-García et al., 2016).

4.4. Palaeoclimatic reconstruction

The bioclimatic variables extracted for the final overlapping area where all species inhabit nowadays, allow us to estimate climatic conditions of the surroundings of Alcoi along the time span represented between El Salt Units Xb and V. All the associations represented in the interval of time analysed in this work show colder conditions than these recorded at the municipality of Alcoi nowadays ($13.64 \pm 0.83\,^{\circ}C$) (Table 3). Nevertheless, regarding rainfall, MAP values obtained for all the samples are very similar to present conditions.

Applying the MER method to samples S9, S8, S7 and V-25, we observed that temperature and mean annual precipitation are generally maintained (Table 3). However, if we compare the values for Unit V with the older unit, temperatures are slightly higher for the upper unit and precipitation is lower. The younger association (V-25) shows a relatively low MTC (similar to the colder conditions obtained for Unit Xb), the lowest values of rainfall among the studied assemblages from Unit V and one of the highest values of MAT and MTW recorded at El Salt (Table 3).

Comparing these palaeoclimatic values from other sites with a similar chronology (Abric Romaní, Cova dels Xaragalls, Canyars and L'Abreda) (Table 4), the tendency observed in the time span represented between Unit Xb and V of El Salt is coincident with the trend shown in levels I–H from L'Arbreda Cave, with an age 45840 - 38290 cal. BP, where MAP and woodlands decrease while MAT increases (López-García et al., 2015).

The average for the MAT values obtained in the different excavation surfaces studied at El Salt ($10.87\,^{\circ}C$) are more similar to the values registered for Cova dels Xaragalls levels C5 and C8 from (López-García et al., 2012a,b) and Abric Romaní level N (Burjachs et al., 2012). These levels have been assigned by these authors to distinct interstadials (IS): IS 15–16 for Abric Romaní level N and Cova dels Xaragalls C8, and IS 13–14 for Cova dels Xaragalls level C5. Regarding the MAP, the previous mentioned levels show similar values to the average for the MAP values (556.59 mm) obtained at Unit V from El Salt. However, other levels also display similar values: Canyars, which has been related to H4 event (López-García et al., 2013), Abric Romaní level J, related to H5 event and K, L and M levels from the same site, which correspond to IS 14 (Burjachs et al., 2012) (Table 4). Clear differences are seen with some levels showing cold climatic conditions such as L'Arbreda Level I, which has been related to a cold period between IS 12-10 (López-García et al., 2015); Cova dels Xaragalls C3 and C4, recognized as a H5, also display a considerable difference with the assemblages studied here (López-García et al., 2012a,b). It seems that our climatic results display a better match with values from levels (from other sites) of a similar chronology linked to interstadials.

Given the climatic values estimated for the Mediterranean region along MIS 3, the climatic parameters obtained here can be placed between values considered for cold and temperate stages, although nearer to temperate ones (Sánchez-Goñi and d'Errico, 2005).

4.5. Thermoclimatic belts

Using ArcGIS software, we linked the areas of the Iberian Peninsula in which the mutual distribution range of the species represented in Unit V overlap and the vegetation maps of Spain (Rivas-Martínez, 1987). The thermoclimaic belts represented in the mutual distribution range comprise from the subalpine to the mesomediterranean belts, where the mesomediterranean (MAT: 13–17C, m: 1–4C, M: 9–14C) and supramediterranean (MAT: 8–13C, m: 4 to −1 C, M 2–9C) stages prevail (Fig. 6). Comparing values for Unit V with those of Unit Xb, a clear change in thermoclimatic belts representation is observed: the supramediterranean belt was predominant in the older unit (Xb), while the

mesomediterranean belt remains the most recurrent one in Unit V. The clearly dominant thermoclimatic stage nowadays in the region is the mesomediterranean stage, while the supramediterranean stage occupies restricted higher areas, mainly in the Font Roja Natural Park and nearby zones (Fagoaga et al., 2018) (Fig. 1).

The absence of the rodent *Microtus agrestis* in the younger units could be explained by the predominance of Mediterranean conditions, which are avoided by this species (Gosálbez and Luque-Larena, 2007). Currently, *M. agrestis* can be found through the Euroasiatic region, while it is absent from every area with mediterreanean influence. Thus, in regards to the Iberian Peninsula, it is present in the northern third mainly occupying meadows and grasslands with Mid European conditions (Palomo et al., 2007).

4.6. Palaeoclimatic and palaeoenvironmental approach

Palaeoenvironmental conditions represented at Unit V of El Salt (chronologically situated between H4 and H5 events) draw a scenario characterized by a drier period with lower mean annual precipitations and higher presence of open dry meadows (Fig. 7D,E) than those of the Unit Xb (Fagoaga et al., 2017). In the same way, results derived from applying the MER method, show a transition from the prevailing supramediterranean (Unit Xb) to mesomediterranean (Unit V) stage, also indicating a change in palaeoecological conditions. In this time span, a deterioration of the climate from temperate and wet conditions to more arid climate occurred. This data together with the increment of Mediterranean species (Fig. 3) matches with percentage values for Mediterranean forest in the SW Iberian margin (Sánchez-Goñi et al., 2008) (Fig. 7B). These results are consistent with different proxies studied at the site as well as others from other sites with the same chronology. Accordingly, in Unit V where the assemblages came from, is associated with aeolian sedimentation (Mallol et al., 2012), possibly related with an increase of wind intensity documented for the Mediterranean region and related with changes in the atmosphere circulation over the North Atlantic region during the D/O stadials and HE (Moreno et al., 2002). TL dating of the roof spall episode and sedimentary deposit in middle of Unit V falls within a H5 time span (Galván et al., 2014b). This event would have occurred after the final Neanderthal abandonment of the site and could be related to cold climatic conditions (Mallol et al., 2012). Moreover, the organic compounds identified and values obtained for the n-alkane chain length ratios point to evidence in the same direction (Galván et al., 2014b).

A strong coupling between environmental dynamics from the continental interior and marine records has been recorded for central Iberia during MIS 2 and 4 (Wolf et al., 2018). Nevertheless, in central Iberia loess deposition between 35 and 50 kyr does not seem to follow a synchronous behaviour of both types of environments. Instead, these authors identified loess dynamics between H5 and H4 (around 41.3 ± 4.0 kyr to 43 ± 3.8 kyr), without any evidence for Neanderthal survival in the entire Iberian interior after 42 kyr (Wolf et al., 2018). They hypothesize the end for the Middle Palaeolithic in this region around that date, corresponding to serious regional climatic deterioration, leading a sparse vegetation cover, which would have affected the availability of key resources for Neanderthals.

A lack of major changes in species diversity in spite of progressive climatic deterioration and the fact that only relative abundances changed (Tables 1 and 2), suggests that climate deterioration did not cause a significant effect in small mammal communities.

Mediterranean influence could play an important role in softening of the climate compared to other regions of the Iberian Peninsula. However, mean annual temperatures for this period were around three degrees less than at present (Table 2). A very similar situation has been recorded at other sites of similar age as L'Arbreda Cave, Cueva del Conde, Gorham's Cave, Cueva Amalda or El Mirón where none of the mentioned sites indicates a major break in microvertebrate associations related with climatic events, with only changes in the relative percentages among different taxa (López-García et al., 2015 and references there in).

Facing the different moments of Neanderthal's extinction at the Iberian macro-region (Fig. 7C), elucidating the context and the causes at the different regions appears as requisite for understanding the reasons that drove these human groups to the end of their evolutionary history.

Overall, climatic deterioration as documented here could represent conditions preceding Heinrich Event 4. Further analysis combining different disciplines are necessary to build a more accurate picture of the climate and landscapes related to Neanderthal demise for the studied region.

5. Conclusions

A study of small mammals from Stratigraphic V allowed us to draw the following conclusions:

- The species *Crocidura* sp., *Oryctolagus cuniculus*, *Microtus arvalis*, *M. cabrerae*, *M. duodecimcostatus*, *Apodemus sylvaticus* and *Eliomys quercinus* are present in all the excavation surfaces analysed. However, *Arvicola sapidus* is present in all except from the youngest assemblage, UE V-25. On the other hand, *Talpa occidentalis* and *Sciurus vulgaris* were only recorded in Surfaces 9 and 7. *Sorex* has only been found in Surface 7, although remains associated to a soricid also have been identified in the other V-24 surfaces (Unit V). Compared to the older unit (Unit Xb), *Erinaceus europaeus* and *Microtus agrestis* which appear at Unit Xb, are not present in Unit V.
- Preliminary taphonomic observation of small mammal remains suggests that the European eagle owl (*Bubo bubo*) as the most plausible agent for the concentration of this assemblage.
- The segment of human depopulation registered at El Salt Unit V is characterized by a palaeoclimatic context where the MAT value is 2.76 °C less than the MAT at El Salt nowadays, and an average MAP value of 13.13 mm less than the current situation. Regarding palaeoenvironmental conditions, woodlands dominated the landscape, although an increase to a more open and arid environment is recorded for the top of Unit V.
- The conditions mentioned above are coincident with the worsening scenario described for the extinction of Neanderthal groups in different regions of the Iberian Peninsula as other proxies have previously shown.
- Given the diachronous and regional nature of the extinction of Neanderthals, the results from this study place El Salt as a reference site for understanding this important bioanthropological event in the East of the Iberian Peninsula.

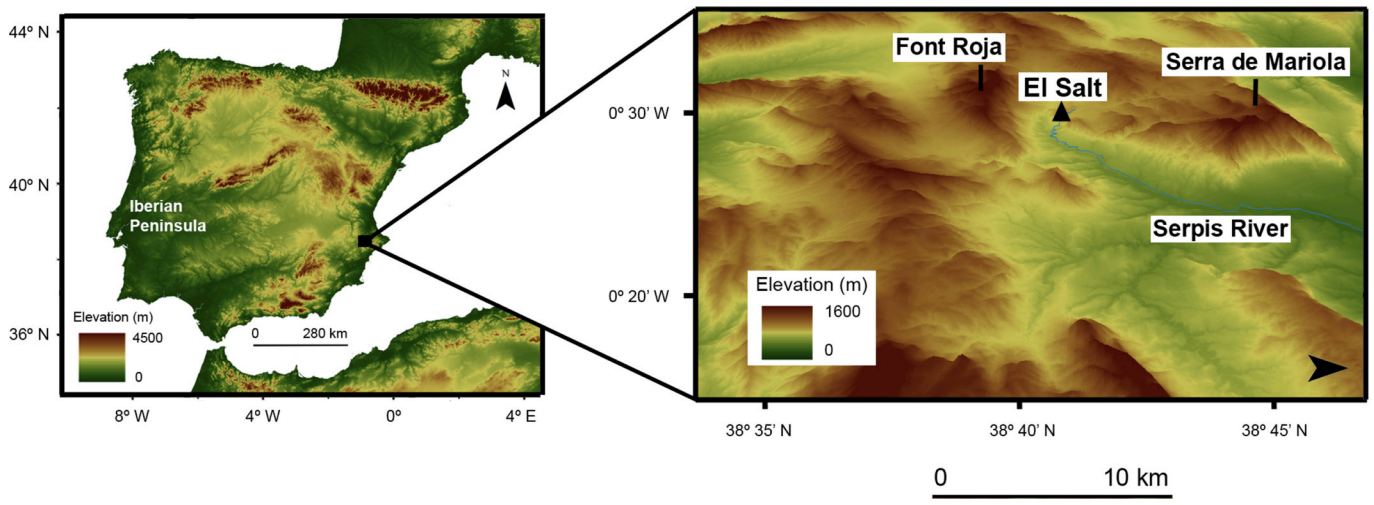

Fig. 1. Geographic location of the Middle Palaeolithic El Salt site in the Iberian Peninsula and its position in the Serpis Valley between Font Roja and Serra de Mariola mountain ranges (http://centrodedescargas.cnig.es/CentroDescargas/index.jsp).

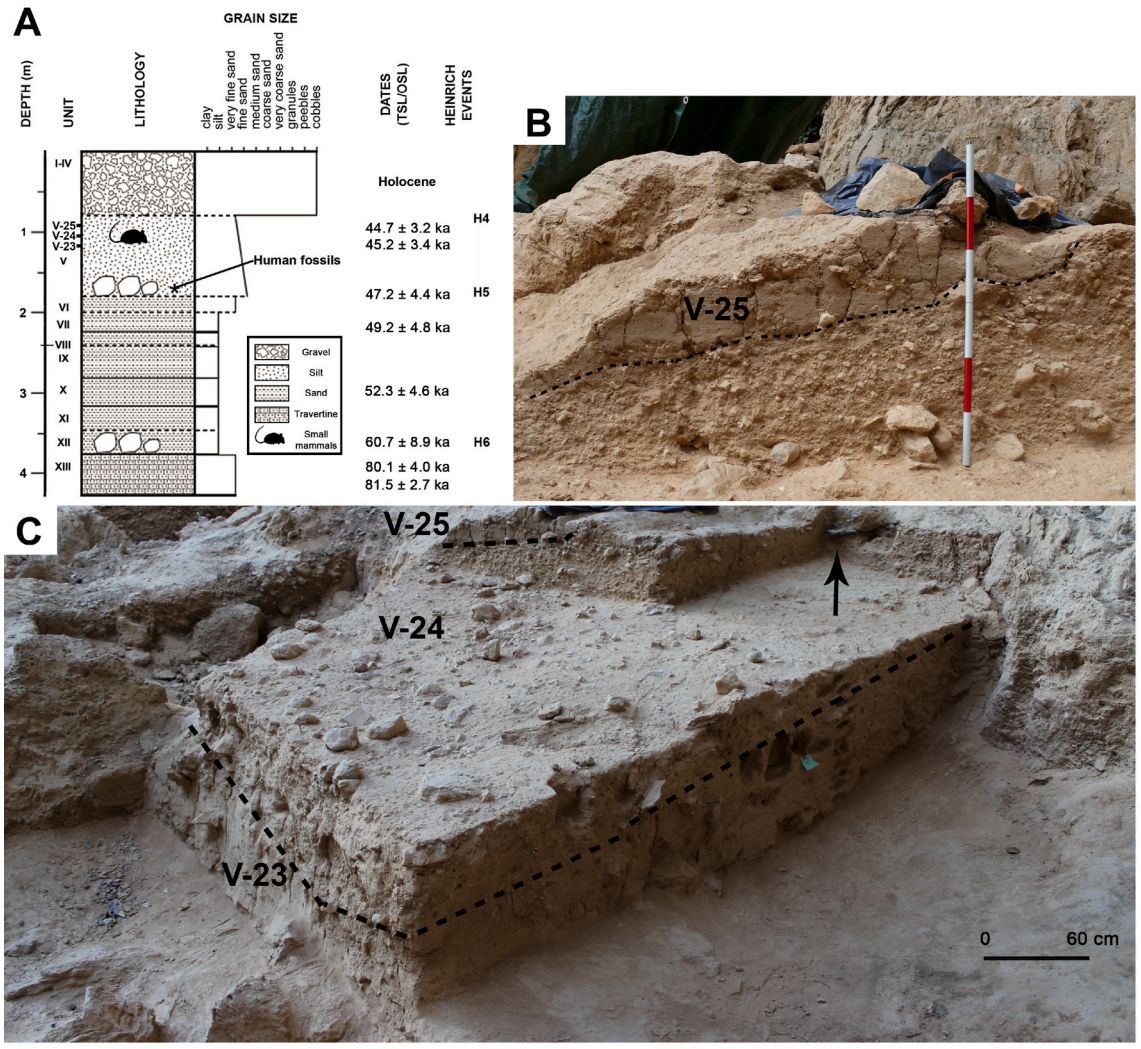

Fig. 2. A) Stratigraphic log indicating position of the small mammals assemblages studied here (modified from Galván et al., 2014b). B, C) Sedimentary deposits of Unit V from which the small mammals assemblage originated (Upper Unit V-24 and V-25) and an underlying segment of the same unit (Upper Unit V-23). The arrow indicates the position of a single hearth found in upper Unit V. Upper Unit V-23 comprises massive silt with isolated millimetric and centimetric fragments of limestone, tufa and bone. Scale bar B, C = 60 cm.

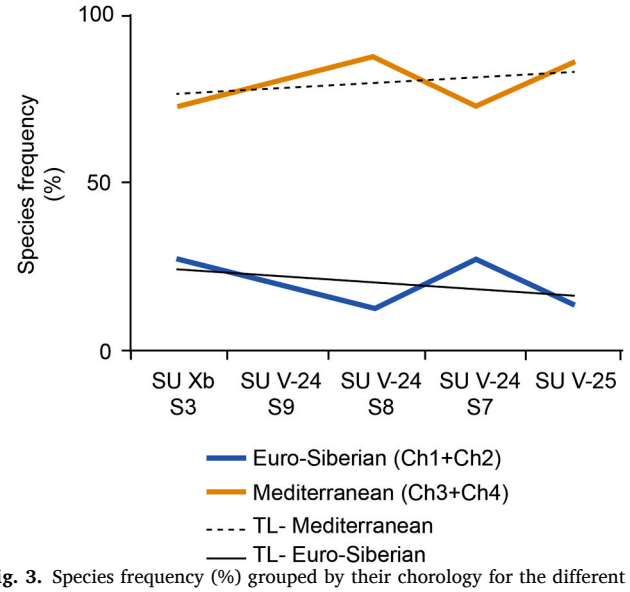

Fig. 3. Species frequency (%) grouped by their chorology for the different assemblages analysed: Mid European requirements and Mediterranean requirements. TL: tendency line; Ch: Chorotype; SU: Stratigraphic Unit; S: Surface (Sans-Fuentes and Ventura (2000), Real et al. (2003) and López-García et al. (2010).

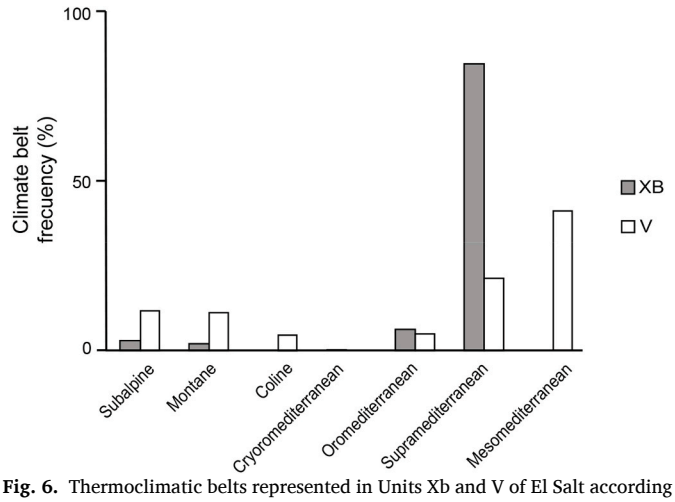

Fig. 6. Thermoclimatic belts represented in Units Xb and V of El Salt according to Rivas-Martínez (1987).

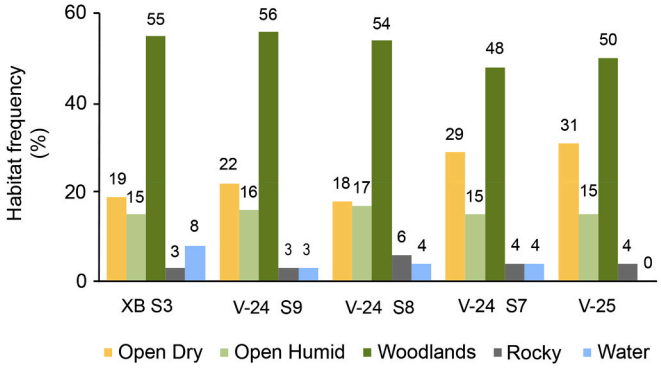

Fig. 4. Palaeoenvironmental reconstruction of the surroundings of the El Salt site for each assemblage studied (XB S3, V-24 S9, V-24 S8, V-24 S7, V-25) (%) (Whittaker, 1948; Rowe, 1956; Gauch, 1989; Cuenca-Bescós et al., 2005).

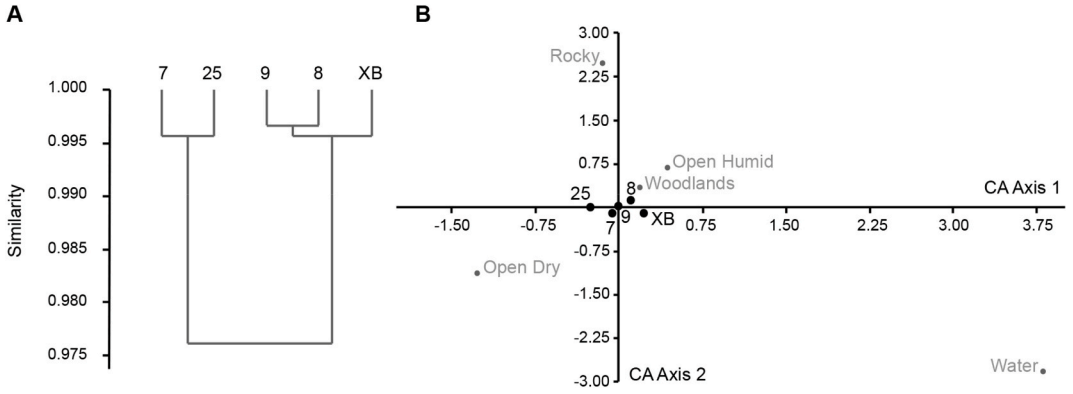

Fig. 5. Cluster analysis (A) and correspondence analysis (B) from the El Salt assemblages.

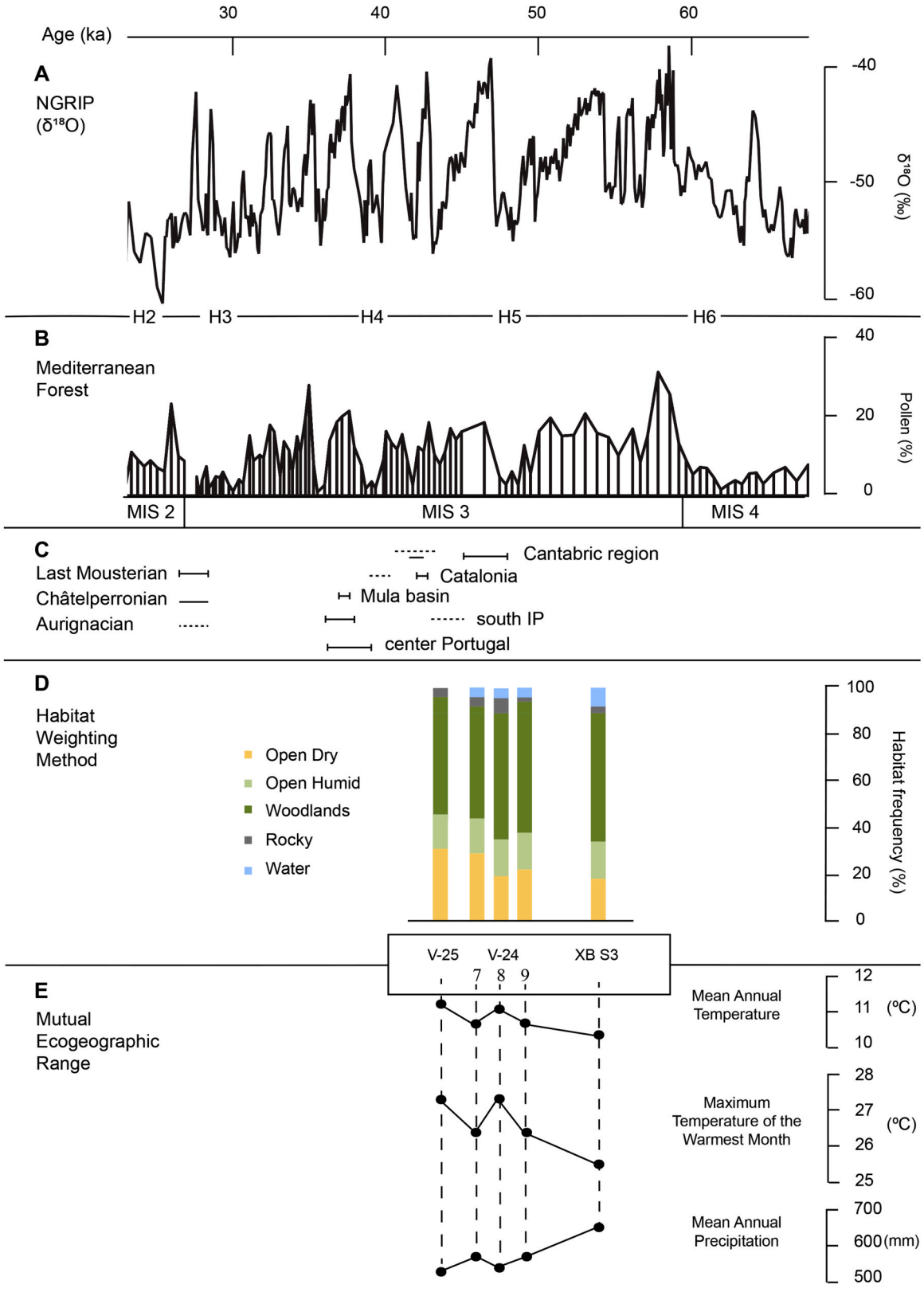

Fig. 7. Palaeoclimatic and paleoenvironmental proxies for MIS 3 and part of MIS 2 and MIS 4, latest Mousterian occupations and chronologies of Châtelperronian and Aurignacian of the Iberian Peninsula. A) Greenland temperature curve (100 years resolution) derived from air and water isotopic measurements (Andersen et al., 2004). B) Pollen percentage curve of the Mediterranean forest (deciduous and evergreen *Quercus*, *Olea*, *Phillyrea*, *Pistacia* and *Cistus*) (Sánchez-Goñi et al., 2008). C) Last Mousterian evidences and chronologies of Châtelperronian and Aurignacian in the Iberian Peninsula (IP) (Zilhão et al., 2007; Higham, 2011; Maroto et al., 2012; Daura et al., 2013; Marín-Arroyo et al., 2018; Cortés-Sánchez et al., 2019). D) Palaeoenvironmental reconstruction of the surroundings of El Salt site for each assemblage studied (%). OH: Open Humid; OD: Open Dry; Wa: Water; R: Rocky; Wo: Woodland. E) Palaeoclimatic reconstruction of the surroundings of El Salt site for each assemblage studied. MAT: Mean Annual Temperature; MTW: Maximum Temperature of Warmest month; MAP: Mean Annual Precipitation.

Table 1
Faunal list from the levels studied at El Salt site and chorotypes for the species identified.[1]

	XB	UPPER V				Chorotypes
		V-24			V-25	
	S.3	S.9	S.8	S.7	–	
Eulipotyphla						
Erinaceus europaeus	1	0	0	0	0	Ch4
Soricidae indet.	0	1	1	1	0	–
Sorex sp.	1	0	0	1	0	Ch2
Crocidura sp.	1	1	1	1	1	Ch3
Talpidae indet.	1	0	0	0	0	–
Talpa occidentalis	0	1	0	1	0	Ch2
Lagomorpha						
Oryctolagus cuniculus	1	1	1	1	1	Ch4
Rodentia						
Arvicola sapidus	1	1	1	1	0	Ch4
Microtus agrestis	1	0	0	0	0	Ch2
Microtus arvalis	1	1	1	1	1	Ch1
Microtus cabrerae	1	1	1	1	1	Ch3
Microtus duodecimcostatus	1	1	1	1	1	Ch3
Apodemus sylvaticus	1	1	1	1	1	Ch4
Eliomys quercinus	1	1	1	1	1	Ch4
Sciurus vulgaris	0	1	0	1	0	Ch4
Total	12	11	9	12	7	

[1] The remains were obtained from water-sieving and flotation of V- 25 and from excavation Surfaces 7, 8 and 9 from V-24. The faunal list from Unit Xb is also displayed (Fagoaga et al., 2017). Value "0" means absence and value "1" presence. Ch1, Chorotype 1 (species with mid-European requirements); Ch2, Chorotype 2 (mid-European species that nonetheless tolerate Mediterranean conditions); Ch3, Chorotype 3 (species with strictly Mediterranean requirements); Ch4, Chorotype 4 (with a broad distribution and without very strict Mediterranean requirements) (Sans-Fuentes and Ventura, 2000).

Table 2
Minimum Number of Individuals, percentage and habitat classification of the species from Units V and Xb from El Salt.[2]

	XB		V								Habitat Weighting				
			24						25						
	S.3		S.9		S.8		S.7		–						
	NMI	%	NMI	%	NMI	%	NMI	%	NMI	%	OD	OH	Wo	R	W
E. europaeus	1.0	2.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0			1		
Soricidae indet.	0.0	0.0	1.0	3.2	1.0	4.0	1.0	3.7	0.0	0.0					
Sorex sp.	1.0	2.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		0.75	0.25		
Crocidura sp.	1.0	2.8	2.0	6.5	1.0	4.0	2.0	7.4	1.0	7.1	0.5		0.5		
Talpidae indet.	1.0	2.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		0.6			0.4
T. occidentalis	0.0	0.0	1.0	3.2	0.0	0.0	0.0	0.0	0.0	0.0		0.5	0.5		
O. cuniculus	5.0	13.9	4.0	12.9	3.0	12.0	7.0	25.9	3.0	21.4	0.8	0.2			
A. sapidus	2.0	5.6	1.0	3.2	1.0	4.0	1.0	3.7	0.0	0.0					1
M. agrestis	1.0	2.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		0.5	0.5		
M. arvalis	5.0	13.9	5.0	16.1	3.0	12.0	2.0	7.4	3.0	21.4	0.5		0.5		
M. cabrerae	2.0	5.6	3.0	9.7	5.0	20.0	3.0	11.1	1.0	7.1		0.5	0.5		
M. duodecimcostatus	3.0	8.3	3.0	9.7	2.0	8.0	2.0	7.4	2.0	14.3		0.5	0.5		
A. sylvaticus	12.0	33.3	9.0	29.0	6.0	24.0	7.0	25.9	3.0	21.4			1		
E. quercinus	2.0	5.6	2.0	6.5	3.0	12.0	2.0	7.4	1.0	7.1			0.5	0.5	

[2] The small mammals from Unit V used for Habitat Weighting Method were obtained from water-sieving of the sediments. Species scores according to their distribution for the Habitat Weighting: Wo, Woodland/Edge-woodland, OD: Open Dry, OH: Open Humid, Wa: Water and R: Rocky (Cuenca-Bescós et al., 2005; Palomo et al., 2007). Dashes indicate that these taxa could not be classified to habitat level.

Table 3
Values of temperature and precipitation for the sequence analysed obtained by MER method and current situation.[3]

	XB		V			NOW
			24		25	
	S3	S9	S8	S7	–	
MAT	10.3	10.7	11.08	10.7	11.03	13.64
SD	1.1	1.5	1.3	1.5	1.27	0.83
Δ	−3.34	−2.94	−2.56	−2.94	−2.61	0
MTW	25.55	26.43	27.28	26.43	27.27	28.49
SD	1.68	2.47	2.06	2.47	1.99	0.59
Δ	−2.94	−2.06	−1.21	−2.06	−1.22	0
MTC	−0.79	−0.67	−0.66	−0.67	−0.76	1.69
SD	1.17	1.36	1.09	1.36	1.13	0.81
Δ	−2.48	−2.36	−2.35	−2.36	−2.45	0
MAP	656.8	578.02	538.48	578.02	531.83	543.46
SD	136.91	173.46	149.55	173.46	140.75	32.99
Δ	113.34	34.56	−4.98	34.56	−11.63	0

[3] MAT (mean annual temperature); MTW (maximum temperature of warmest month); MTC (minimum temperature of coldest month); MAP (mean annual precipitation); NOW (current situation). SD (standard deviation of values obtained); Δ (difference between the values obtained by analysing the small mammals and current values).

Table. 4
Values for temperature and precipitation for four Iberian archaeological sites.[4]

SITE	LEVEL	MAT	MAP	Δ MAT	Δ MAP
Abric Romaní	E	7.8	809.00	−3.08	252.41
Abric Romaní	J	9.8	719.00	−1.08	162.41
Abric Romaní	K	9.8	719.00	−1.08	162.41
Abric Romaní	L	9.8	719.00	−1.08	162.41
Abric Romaní	M	9.8	719.00	−1.08	162.41
Abric Romaní	N	10.7	734.00	−0.18	177.41
Abric Romaní	O	7.8	1009.00	−3.08	452.41
Arbreda	B	9.6	926.70	−1.28	370.11
Arbreda	C	9	850.00	−1.88	293.41
Arbreda	H	8.4	950.00	−2.48	393.41
Arbreda	I	6	1500.00	−4.88	943.41
Canyars	–	10.11	757.60	−0.77	201.01
Xaragalls	C3	7.92	1092.00	−2.96	535.41
Xaragalls	C4	8	925.00	−2.88	368.41
Xaragalls	C5	10.36	664.00	−0.52	107.41
Xaragalls	C6	8	950.00	−2.88	393.41
Xaragalls	C7	8.67	900.00	−2.21	343.41
Xaragalls	C8	10.48	729.00	−0.40	172.41

[4] MAT (ºC) and MAP (mm) for the sites Abric Romaní, L'Arbreda Cave, Canyars and Cova dels Xaragalls (López-García et al., 2012a,b). ΔMAT and ΔMAP show the difference between values from those sites and the mean of temperature and precipitation values from the studied unit (10.88 °C; 557 mm).

Acknowledgements

Research at El Salt is funded by the Spanish Government project HAR 2015-68321-P (MINECO FEDER/UE), UV-INV_AE17-708551 (University of Valencia) and Conselleria d'Educació, Investigació, Cultura i Esports from the Valencian government. This investigation was also carried out thanks to the Prometeo Project of the Secretariat for Higher Education, Science, Technology and Innovation from Ecuador and the University of La Laguna (Tenerife, Spain). We would like to thank the whole team of El Salt for their effort and dedication during the field excavations and laboratory tasks. We also thank the Alcoi Archaeological Museum and the Town Hall of Alcoi for their support and finally, the anonymous reviewers who helped improve the paper.

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